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GSFC

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GREENBELT, MARYLAND

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AUGUST 1971

ABSTRACT

Recent satellite observations have shown that "auroral hiss", covering the frequency range from a few kHz to several hundred kHz, is a common phenomenon in polar regions. To deduce the origin of this hiss, we have compared the records of a VLF experiment (0.3 - 18 kHz) with simultaneous data obtained by an auroral particles experiment having detectors for precipitating electrons at 0.7, 2.3, and 7.3 kev. We have found that on the dayside of the earth, the occurrence of VLF hiss correlates well with precipitation events at 0.7 kev, but in general very poorly with activity in the higher-energy channels. Exact correlation between variations in VLF hiss intensity and in electron fluxes is rare even at 0.7 kev. In addition, VLF hiss tends to be observed over a somewhat larger spatial region than precipitating 0.7 kev electrons. We conclude that on the day-side, auroral hiss is generated by soft ($E < 1$ kev) "cusp region" electrons and that the lack of detailed correlation between the two phenomena is caused by propagation effects as the hiss travels downward and spreads from the generation region. Further study is required of observations made on the nightside, where VLF hiss may correlate with fluxes of harder electrons.

INTRODUCTION

To explain some observations of radio noise at 520 kHz which did not appear to be of cosmic origin, Ellis [1957] proposed that "auroral particles approaching the earth" may emit radiation by the Cerenkov process "throughout a frequency band extending from hundreds of kilocycles per second to low audio-frequencies" and that the intensity of the radiation may be sufficient to make it observable at the ground. This suggestion was indeed soon followed by a number of reports directly linking auroras with radio noise at VLF frequencies [Duncan and Ellis, 1959; Martin et al., 1960; Jørgensen and Ungstrup, 1962]. The broadband nature of the phenomenon was demonstrated by Dowden, who reported the simultaneous occurrence of the noise at 4.6, 9.6, 27, 70, and 180 kHz [Dowden, 1959], and also at 9 and 230 kHz [Dowden, 1960]. The term "auroral hiss" was apparently first used by Martin et al. [1960] to distinguish hiss associated with auroral phenomena from other types of VLF hiss.

With satellite-borne VLF receivers it became possible to study the morphology of auroral hiss above the absorbing lower ionosphere. On the basis of Injun 3 data, Gurnett [1966] reported that VLF hiss below 8.8 kHz occurred mostly between noon and midnight magnetic local time (MLT) and that the region of occurrence was typically about 7^{o} wide, centered on 77^{o} invariant latitude (INV) at 12 hrs. MLT, and decreased to 72^{o} INV at 23 hrs. MLT. Using simultaneous data from electron detectors at 10 and 40 kev, Gurnett also showed that VLF hiss was related only to the softer (10 kev) electrons in the evening hours.

The results further suggested that during local afternoon VLF hiss was probably related to electrons whose energies were not great enough to cause a response from the 10-kev detector.

Hartz [1969] subsequently made a survey of radio noise at 200 kHz using the data of the Alouette 2 broadband receiver and found a high-latitude region of maximum intensity on the dayside of the geomagnetic pole in the range 75^{o} - 80^{o} INV. From the noon meridian the intensity contours extended into the morning and the evening hours with a gradual reduction in intensity and latitude. Interpreting his results in the light of the measurements on soft electrons that had become available since Gurnett's [1966] study, Hartz concluded that the radio noise he observed probably arose as Cerenkov radiation from the influx of electrons in the range 0.1 to 1 kev into the dayside "cusp region".

Very recently a study of "auroral hiss" has been performed by Laaspere et al. [1971] using the data from an OGO-6 experiment which includes four broadband receivers (0.02 - 15 kHz, 15 - 30 kHz, 92.5 - 107.5 kHz, and 280 - 295 kHz), two narrow-band receivers at 200 and 540 kHz, and a broadband intensity detector. The study included results on the variation of auroral hiss intensity from audio frequencies to 540 kHz and a discussion of the changes in the location of the "auroral hiss zone" as a function of geomagnetic activity. Making use of the broad frequency coverage available in the experiment, Laaspere et al. [1971] demonstrated that auroral hiss typically extends from a few kHz to at least 540 kHz. (Hartz [1969] has stated that on the high-frequency side the auroral hiss band usually terminates at about 0.9 times the electron gyrofrequency at the satellite).

Since the results of both Gurnett [1966] and Hartz [1969] pointed to a direct relation between auroral hiss and the precipitation of soft electrons, the present authors felt that a correlation study between these two phenomena should be performed using simultaneous data. Further impetus for the present study of events in detail arose from the general relationship found between the region of soft electron precipitation as studied by one of the authors with OGO-4 data [Hoffman and Berko, 1971] and the locations of the centers of the auroral hiss zone at 200 kHz as observed by the other author with OGO-6 data [Laaspere et al., 1971]. The superposition of these two data sets appears in Figure 1. The two shadings in the figure refer to areas in magnetic local time and invariant latitude where structured 0.7 kev electrons have high probability of being observed. This region has been identified with the dayside soft zone and the dayside auroral oval in the hours from about 0500 to 1800 MLT. For purposes of comparison, the VLF data were selected on the same basis of magnetic activity ($K_p \leqq 2$) as the particle data. It should be noted that aside from a few isolated points, the centers of 200-kHz auroral hiss events fall remarkable well within the region of this type of electron precipitation, even during the nighttime hours.

INSTRUMENTATION

The auroral hiss and low-energy electron data used in our correlation study were obtained by two experiments flown on the OGO-4 spacecraft, which was launched on July 28, 1967, into a nearly polar (86^{o}) orbit with an apogee and perigee of about 900 and 400 km, respectively.

The particles experiment contained an array of eight detectors, each comprised of an electrostatic analyzer for particle species and energy selection and a channel electron multiplier as the particle detector. This study will make use of data from three of the detectors, all positioned to measure electrons moving radially towards the earth. In the high latitude region, where the magnetic field lines have inclinations near 90^{o}, the particles measured had pitch angles near 0^{o}. The bandpass of each detector was +19%, -13% of the center energy, which is listed in the figures with the appropriate data. Additional details about the experiment appear in Hoffman and Evans [1967].

Auroral hiss was observed by a VLF receiver which covered the frequency range from about 300 Hz to 18 kHz and was connected to a 9-foot-long electric dipole antenna. The receiver had four gain positions which could be selected by ground command. In each gain position a calibration signal of known intensity was generated in the receiver and inserted into the preamplifier to serve as a reference level for signals received by the antenna. This calibration signal can be identified in most frequency vs. time records of the VLF data presented in this paper as a dark line at 8 kHz. In some cases the line

may, however, be masked by a high level of spacecraft-generated interference at the harmonics of the spacecraft's 400 Hz power supply and the 2461.5 Hz "sync signal".

Most of the VLF records shown in the paper were obtained with the experiment in the third gain position. In this receiver setting the equivalent input level of the calibrate oscillator is 140 μV. In the November 13, 1967, event of Figure 4 the receiver was in the fourth (highest) gain position (calibrate signal level 36 μV), and the event shown in Figure 7 was obtained in the second gain position (calibrate signal level 680 μV). Since the darkness of the signal traces in the VLF records is an indication of their relative intensity, a rough estimate of the intensity of VLF hiss in the effective bandwidth of the spectrum analyzer ($\simeq$ 100 Hz) can be obtained from visual inspection alone. For example, during its most intense portion, auroral hiss in Figure 2 completely masked the calibrate oscillator signal. Thus its maximum intensity at 8 kHz must have been greater than 140 μV in a 100 Hz band.

To estimate the intensity of the ambient electric field, it must first be pointed out that the balanced input impedance of the receiver was relatively low (200 kilohms), so that under some conditions an appreciable fraction of the voltage developed in the antenna may have been lost across the series impedance of the antenna which depends in a complex manner on the characteristics of the ionospheric plasma. Even if this loss is neglected, an effective antenna length of 3 meters would lead to an ambient electric field greater than about 5 $\mu V/m/Hz^{\frac{1}{2}}$

at 8 kHz during the most intense portion of the event shown in Figure 2. The corresponding power flux would probably be at least of the order of 10^{-13} watts/m^2/$Hz^{\frac{1}{2}}$, but estimates of power flux from electric field measurements alone are highly unreliable, especially near the lower hybrid resonance frequency. It must also be pointed out that the durations of VLF events deduced from the onset and termination times given in the paper must to some extent be considered as lower bounds, since interference, telemetry noise, and noise introduced in the data processing operations would tend to mask weak auroral hiss. More will be said about this in later sections of the paper.

COMPARISON OF SIMULTANEOUS DATA

The first illustration of the simultaneous occurrence of less than one kev electron precipitation and broadband VLF auroral hiss is shown in Figure 2. These data were acquired in the early afternoon hours as the satellite transited the entire soft zone, which extended from about 0332:22 to 0333:43 UT. The maximum electron fluxes encountered reached nearly 10^{10} electrons/(cm^2-sec-ster-kev), and were centered within the region of auroral hiss. The hiss actually extended about ten to twenty seconds on both sides of the particle precipitation region, although at a considerably reduced intensity.

Four additional examples of simultaneously occurring regions of 0.7 kev electron precipitation and auroral hiss, all occurring in the morning hours, appear in Figure 3. The upper two examples show the low latitude onset of the soft zone at 1906:06 UT and 1911:10 UT respectively, at which times hiss also abruptly began. In both cases data acquisition from the particle detectors ceased before the entire soft zone was traversed, but VLF hiss appeared to terminate even sooner. In the case of the first event (Nov. 9), we have independent evidence from another VLF experiment (see Discussion) that weak VLF hiss bursts actually continued until the end of the record. Since the VLF hiss of the second event (Nov. 13) was also weak relative to the background noise and spacecraft-generated interference, we do not feel that its apparent early termination is significant.

The third event of Figure 3 (Jan. 3) is an entire crossing of the soft zone, which was observed from 0013:57 to 0016:03 UT. In this case hiss extended on either side of the precipitation region for about 30 seconds (or about 1^{o} invariant latitude).

In the final example in Figure 3 the VLF record included the entire event, with hiss commencing at about 1719:22 UT and extending until about 1721:20 UT. Unfortunately the acquisition of particle data began at 1719:24, so an onset correlation was not possible. While there does appear to be an offset in latitude between the regions of maximum particle and hiss intensities, both phenomena disappeared into background levels on the high latitude side at nearly the same time.

The five examples which were displayed in Figures 2 and 3 demonstrated a general correspondence between the occurrence of auroral hiss regions and the soft zone as defined by measurements of precipitating electrons at 0.7 kev energy. The next example (Figure 4) illustrates a lack of correlation between auroral hiss and the precipitation of higher energy electrons. Electron fluxes at the three energies of 0.7, 2.3 and 7.3 kev are plotted with the VLF record for a morning hour pass. The hard zone [Hoffman, 1969], characterized by relatively unstructured precipitating electrons at all energies, began before any hiss was observed, although the location of the lower boundary appears to be a function of the energy of the electrons. The upper boundary of the hard zone, usually identified with the last closed field line [Winningham, 1970; Frank, 1971] occurred at 2150:28 UT where the 2.3 and 7.3 kev fluxes suddenly decreased by more than an order of magnitude. The soft zone slightly overlapped the hard zone, commencing with the structure in the 0.7 kev flux at 2150:24 UT. While the hiss extended into the hard zone by nearly 30 seconds, though with reduced intensities, most of it occurred in the region of the structured, 0.7 kev electron precipitation.

We next investigate whether there exists a detailed correlation between individual particle precipitation structures and burst structure in the VLF hiss. Figure 5 contains three high time resolution records of the 0.7 kev flux and auroral hiss which demonstrate that in general there is little detailed correlation between the two phenomena. Note in the November 5 event the VLF burst at 1720:08 at a time when the particle flux was less than 10^8, compared to the weak hiss from 1719:30 to 1719:36 UT in the region of maximum electron precipitation; in the November 12 pass the very intense electron bust at 1844:50 UT which followed 20 seconds of intense hiss; in the January 3 event the greater than 10^9 electron fluxes from 0014:15 to 0014:20 UT in a region of weak hiss, followed by ten seconds of stronger hiss while the particle fluxes had decreased by an order of magnitude.

On the other hand, there do exist cases of detailed correlation. The sharp structure in the electron precipitation pattern at 0014:49 in the January 3 event of Figure 5 had a several second burst of hiss surrounding it, and the simultaneity between the maximum particle flux and the intense hiss at 0015:00 is even more apparent. The sudden onset of the hiss in the form of a isolated "riser" and the first electron precipitation structure at 1911:13 in the November 13 event of Figure 3 is extremely striking.

Because these data records contain broad regions of considerable structure both in electron precipitation and in auroral hiss, the possibility of accidental coincidences cannot be overlooked. For this reason we sought more isolated and highly discrete events for direct

correlation. The upper half of Figure 6 contains two such correlations: the double peaked electron structure at 2057:09.5 had a double emission especially evident from 8 to 18 kHz preceding it by a few tenths of a second; the double emission at 2057:16 occurred exactly in coincidence with the double peaked electron burst.

An even more isolated event is shown in the lower half of Figure 6, where a two-second VLF burst is clearly associated with the double peaked electron burst, which was observed only in the 0.7 kev channel. This observation was made on the nightside of the earth in contrast to all previous examples, but the invariant latitude of the correlation event ($\simeq 79^{o}$) is more typical of dayside conditions than auroral zone phenomena. The background noise in the VLF record started to increase rapidly at about 1112:47 UT, but the records have been displayed up to 1112:53 to demonstrate the isolated nature of the electron burst. The VLF signal intensity record shown was obtained through a 2-kHz filter centered at 6 kHz. Typical signal fluctuations in the record were of the order of several db, but in the VLF burst at 1112:39 UT the signal intensity increased by more than 10 db. The intensity scale is highly nonlinear, however, and the record should be viewed mainly as an aid in visualizing signal fluctuations.

Except for the event of Feburary 7 of Figure 6 that has just been examined, all of the particle-VLF correlations discussed above occurred on the dayside, and especially in the morning hours. We have shown that VLF hiss in these events was related to very soft electron fluxes, i.e., fluxes below 1 kev. In contrast, VLF hiss occurring during the substorm event shown in Figure 7 appears to be better correlated with

much more energetic electrons. In particular, the onset of the VLF hiss event at 0839:50 occurred coincident with the low latitude boundary of 7.3 kev electron precipitation and temporarily terminated with the loss of particles at 0840:33. Weaker and more sporadic VLF hiss continued at least until 0841:10, although no appreciable electron fluxes were observed at 0.7 kev or above. This set of data was acquired in the pre-midnight hours during a magnetically active period. A series of small substorms had been occurring for seven hours preceding the pass, but at the precise time of data acquisition the magnetic field as measured at Churchill (0.5 hrs. MLT) and College (21 hrs. MLT) had returned nearly to normal.

DISCUSSION

In this study we have attempted to demonstrate the general spatial or temporal correlation between the existence of soft electron precipitation and VLF auroral hiss, especially in the dayside hours.

We have shown that in the dayside hours the hiss correlates with the electron precipitation occurring in the soft zone, i.e., with less than 1 kev electrons, and not with the higher energy electrons which form the lower latitude hard zone. Using Injun 5 data, Gurnett and Frank [1971] have arrived at the same conclusion in a recent independent study. The onset of VLF hiss has been observed by us to be nearly simultaneous with the onset of the soft electron precipitation (Nov. 13 event and perhaps the Nov. 9 event in Figure 3), but more often it is found to spread beyond the soft zone by one to 1-½ degrees (Figure 2, the Jan. 3 event in Figure 3, and Figure 4). We have also shown that the correlation is primarily one of general regions, not of individual structures, although in a few cases these have also been observed.

The situation in the nighttime hours may not be identical to the daytime. In the nighttime auroral zone event studied the correlation was with the precipitation of electrons with energies at least an order of magnitude larger than on the dayside, i.e., with those electrons which carried the energy into the atmosphere and would produce the common auroral optical emissions. In addition the hiss was more continuous in form, rather than showing temporal and spatial structure. It should be pointed out that there is other observational

evidence [Gurnett, 1966] that VLF auroral hiss may correlate on the nightside with harder electrons than on the dayside.

The explanation of these experimental results is not completely clear. Jørgensen [1968] has indicated that contrary to a number of earlier estimates, the power emitted by precipitating electrons in the incoherent Cerenkov process may be sufficient to explain the observed power fluxes of auroral hiss. However, since Jørgensen used a model in which hiss was generated by electrons with energies above 1 kev along field lines intercepting the earth at 70° geomagnetic latitude, his calculations are more appropriate to the nightside hard zone than to the dayside soft zone.

The total power emitted by the Cerenkov process can be calculated from the expression

$$P = P_e \cdot N_e \cdot V$$

where P_e is the average power emitted per electron, N_e is the number density of the emitting electrons, and V is the volume containing the electrons. Jørgensen [1968] found in his calculations that P_e was inversely proportional to the square root of the particle energy. Also, as we move to higher latitudes, the volume of a tube of flux with a unit cross-sectional area at ionospheric heights will increase. A careful recalculation of the Cerenkov process similar to that performed by Jørgensen [1968], but carried out for a model appropriate to the dayside of the earth, may well show that association of VLF auroral hiss with the dayside soft zone precipitation is just what should have been expected.

If we assume that the boundaries of particle precipitation also define the lines of magnetic force enclosing the region of hiss generation, the observation of VLF hiss beyond the region of electron precipitation indicates the propagation of VLF waves across magnetic field lines. The extent of this spreading under various circumstances is not clear and should be studied further by use of simultaneous VLF and particle data. It is known, however, that even on the dayside of the earth, auroral hiss may occasionally cover a latitude range of up to 20 degrees [Laaspere et al., 1971]. Because of this spreading, and also because the "local responses" of the VLF antenna and the particle detectors are different (one accumulation period allows the acquisition of particle flux over a region one millimeter wide by about 300 meters along the path of the satellite), the generally poor correlation between VLF hiss bursts and particle precipitation structure is not surprising.

An interesting effect sometimes observed is the sudden increase in the low frequency cutoff of the hiss at times of electron flux enhancements. This is especially noticeable at the two structures of electron precipitation at all energies immediately above the high latitude boundary of the hard zone at 2150:30 and 2150:35 UT in Figure 4. This variation in the low frequency cut-off could also account for the apparent decrease in hiss intensity at 1844:50 to 1844:52 for the November 12 event in Figure 5, where the large 0.7 kev flux also occurs just above the upper boundary of the hard zone. If these intense regions of electron precipitation seemingly associated with the hard zone boundaries are a relatively stable feature

in comparison to the more usual soft zone precipitation, the ambient electron and ion densities in the vicinity of the satellite could be considerably perturbed [Sato and Collin, 1969]. Therefore the low frequency portion of the hiss could perhaps be excluded from propagating to the satellite by a localized increase in the lower hybrid resonance frequency.

The payload of OGO-4 also included a VLF experiment supplied by Stanford University (Prof. R. A. Helliwell, Principal Investigator) which was connected to a 9.5-foot-diameter loop antenna and was a highly sensitive detector of the magnetic component of VLF waves [Ficklin et al., 1965]. Through the courtesy of Dr. T. F. Bell of Stanford University, we have obtained the simultaneous broadband records (0.1 - 13 kHz) of their receiver for two of the events of Figure 3 to check on the similarities and differences of the electric and magnetic field data. An inspection of the records has shown that the burst structure of VLF hiss is similar in both sets of data, but the duration of the events as detected by the Stanford experiment is somewhat longer. Thus, in the first event (November 9, 1967) shown in Figure 3, the electric component of the VLF hiss was first detected at about 1906:06 UT whereas the first indication of hiss in the magnetic component (Stanford) was at about 1905:50 UT, i.e., about 16 seconds earlier. Also, in our record hiss appeared to terminate at about 1907:05 UT, but in the magnetic component weak hiss bursts were observed until about 1907:40. In the last event of Figure 3, the magnetic component of the hiss started abruptly essentially simultaneously with ours, but whereas hiss in our record disappeared into

background noise at about 1721:22 UT, some hiss bursts were evident in the Stanford data until about 1721:50 UT. The Stanford results thus reinforce our conclusion that VLF auroral hiss in general covers a broader range of invariant latitudes than 0.7-kev precipitation.

The similarity in the fine structure of electric and magnetic components of VLF auroral hiss as found from a comparison of Stanford and Dartmouth data, together with our earlier observation of a general lack of correlation of burst structure of the electric component of the hiss with the details of 0.7-kev precipitation, points to a similar lack of correlation of the power flux of VLF auroral hiss with 0.7-kev precipitation.

We can say very little about the relationship between the instantaneous or the average total energy in low-energy precipitation events and in auroral hiss. First, the majority of the electrons precipitating in the dayside soft zone have energies less than the lowest energy detector in the particle experiment. Utilizing the energy spectrums of Heikkila and Winningham (1971) we have estimated that the flux measured in the bandpass of the 0.7 kev detector accounts for about 5% of the total integrated flux in this region. As a result, data from this lowest energy channel can only be used to define the extent of the soft zone and not its intensity. Similarly, the VLF experiment measured only the electric component of auroral hiss up to 18 kHz, but even if the power flux of hiss could have been determined in this frequency range, it is now clear that the auroral hiss spectrum extends to several hundred kHz and shows considerable variation between individual events [Hartz, 1970; Laaspere et al., 1971].

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FIGURE CAPTIONS

Figure 1. A superposition of the centers of the auroral hiss zone at 200 kHz as observed on OGO-6 (dark circles) (Laaspere et al, 1971) on the probability of occurrence of 0.7 kev structured precipitation on OGO-4 (Hoffman and Berko, 1971) Only events for which $K_p \leq 2$ were included in both studies.

Figure 2. An event illustrating positive correlation between precipitating 0.7 kev electrons and VLF hiss observed simultaneously. The numbers on the ordinate of electron data give the logarithms of electron flux in electrons/(cm^2-sec-ster-kev). The data were acquired on April 22, 1968 at about 14.3 hrs. MLT.

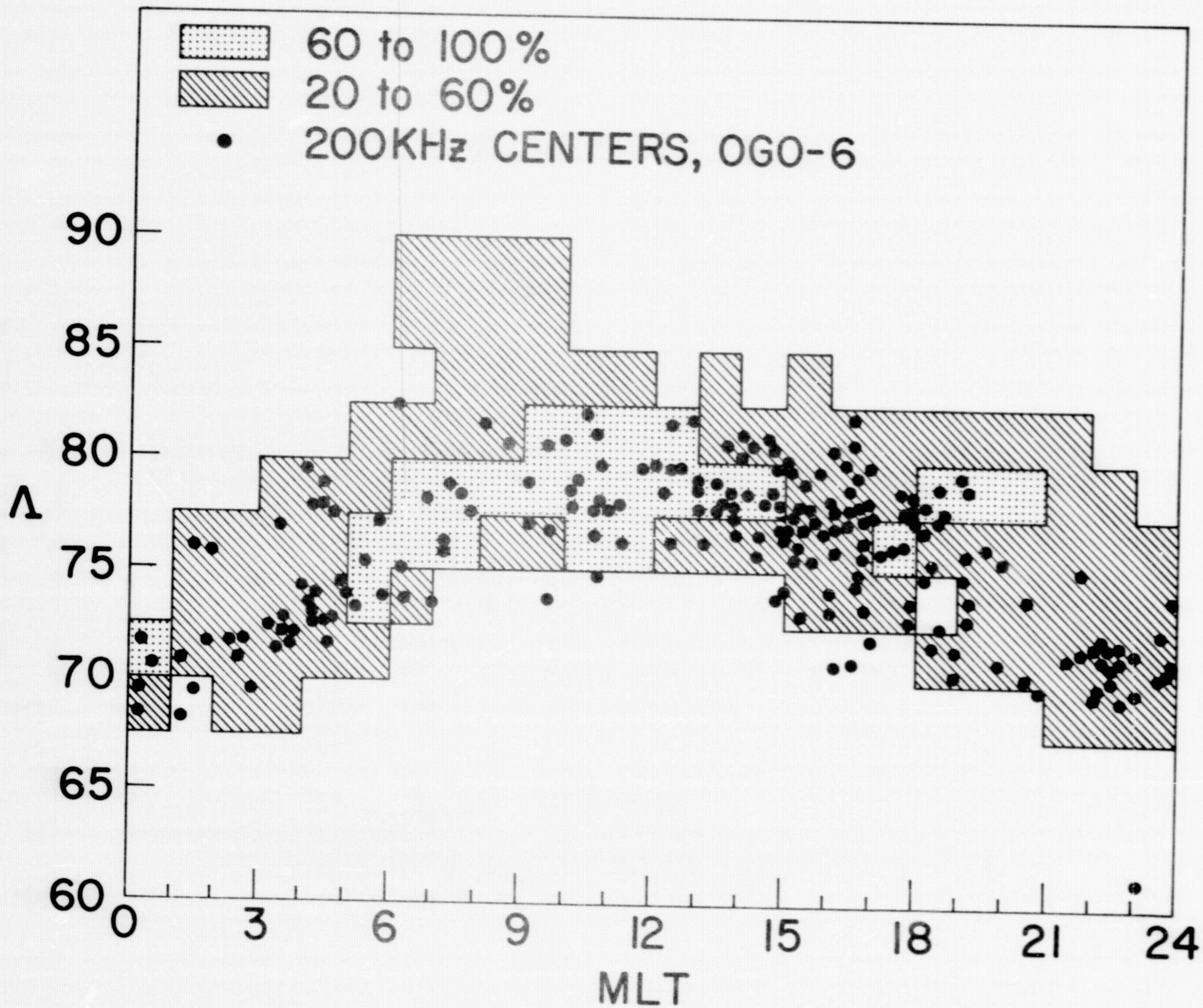
Figure 3. Four additional correlation events between VLF auroral hiss and precipitating 0.7 kev electrons which occurred in the morning hours.

Figure 4. A correlation event on Nov. 4, 1967, at 7.8 hrs. MLT, illustrating the relationship between VLF auroral hiss and the hard and the soft regions of electron precipitation in the morning hours. The upper boundary of the hard zone occurred at 2150:28 UT.

Figure 5. Three high time-resolution events illustrating a general lack of correlation between fine structure of VLF hiss and that of electron precipitation.

Figure 6. High time-resolution events displaying detailed correlation between VLF hiss bursts and the spikes in low-energy electron precipitation. See text for detailed explanation.

Figure 7. A correlation event near midnight obtained during a magnetically disturbed period showing the relationship of auroral hiss with the precipitation of energetic electrons.



60 to 100%
20 to 60%
200KHz CENTERS, OGO-6
Λ
90
85
80
75
70
65
60
0
3
6
9
12
15
18
21
24
MLT

FIGURE 1

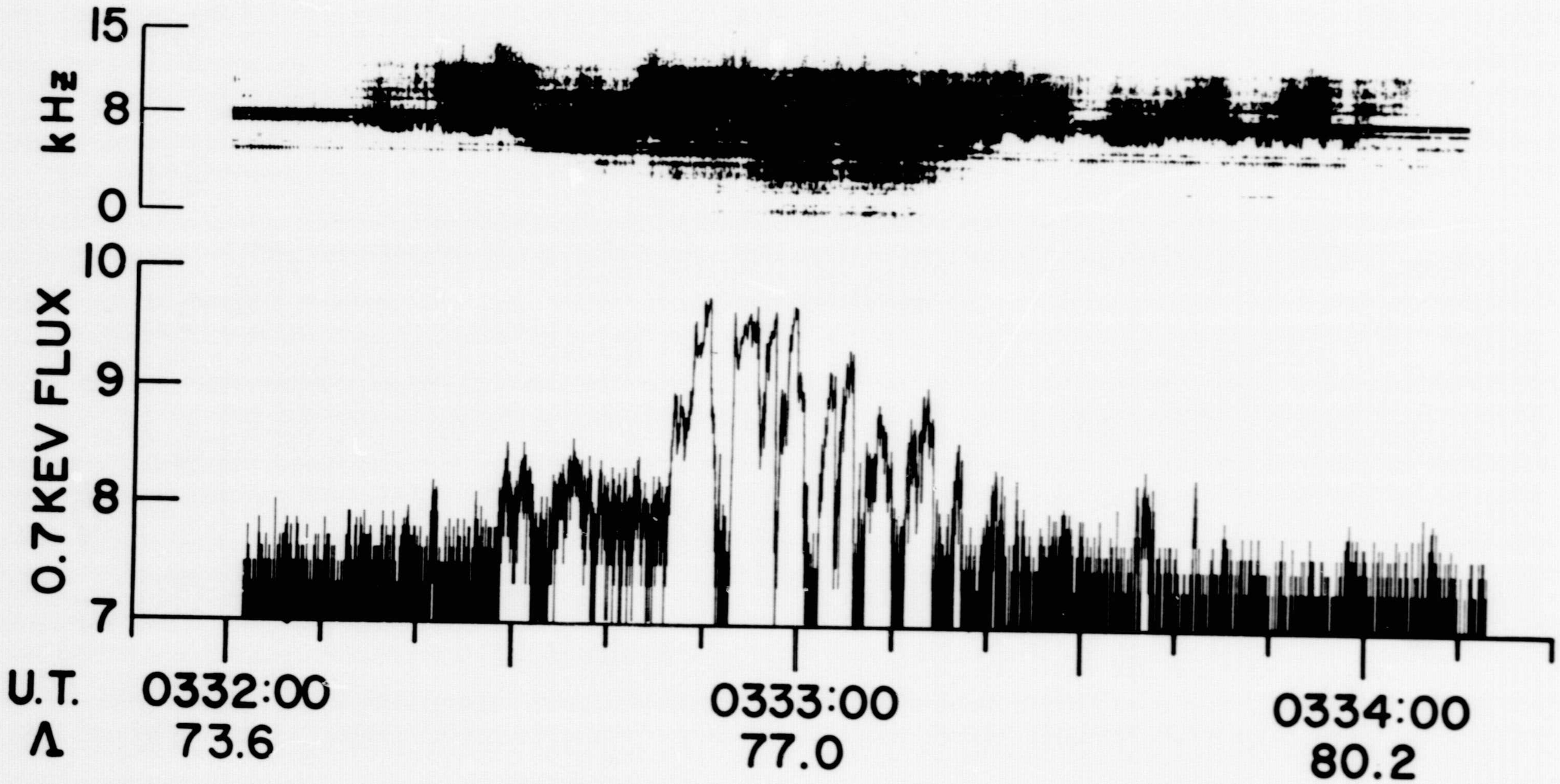
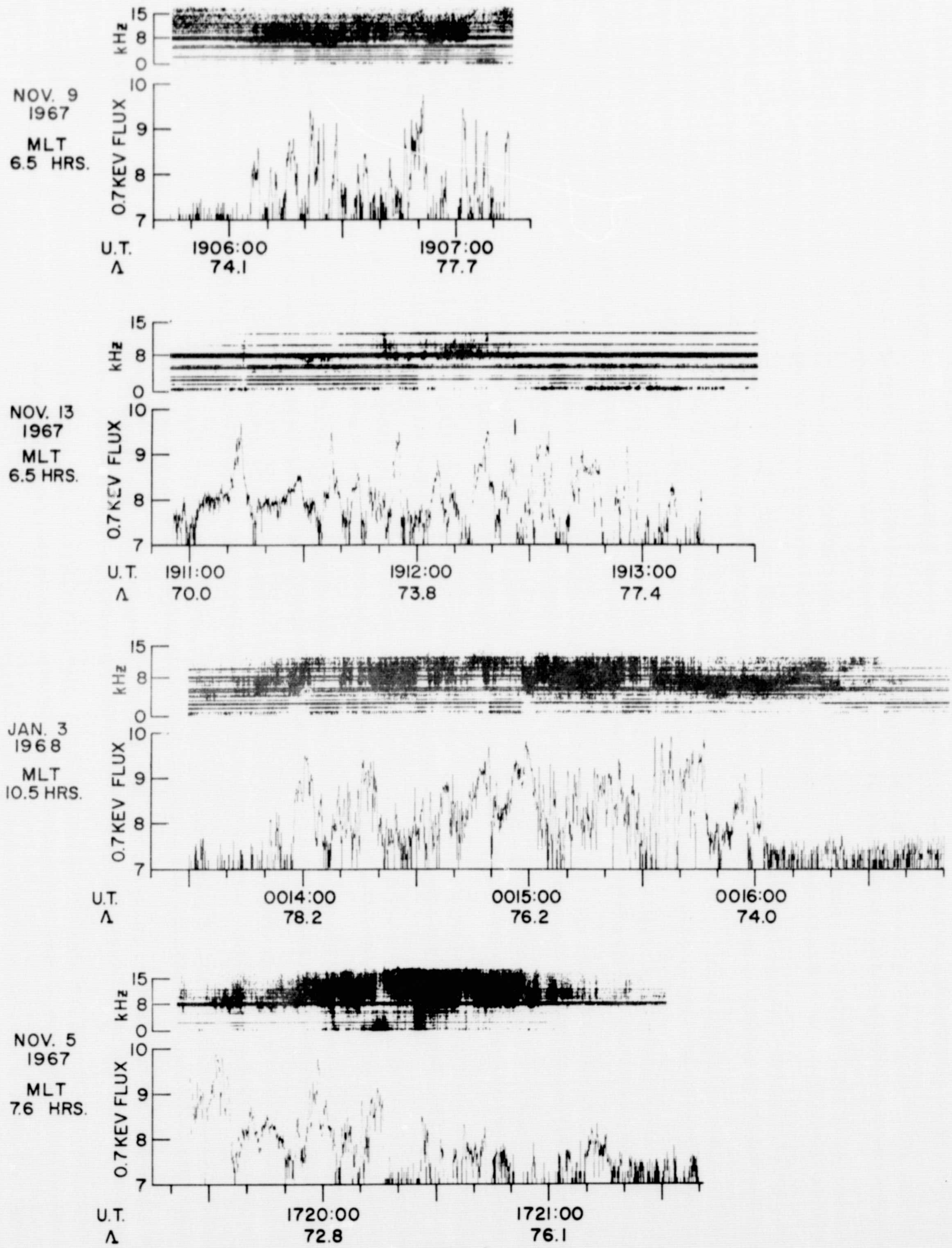

15
8
0
kHz
10
9
8
7
0.7KEV FLUX
U.T.
Λ
0332:00
73.6
0333:00
77.0
0334:00
80.2

FIGURE 2



15
kHz
8
0
NOV. 9
1967
MLT
6.5 HRS.
10
9
8
7
0.7KEV FLUX
U.T.
Λ
1906:00
74.1
1907:00
77.7
NOV. 13
1967
MLT
6.5 HRS.
U.T.
Λ
1911:00
70.0
1912:00
73.8
1913:00
77.4
JAN. 3
1968
MLT
10.5 HRS.
U.T.
Λ
0014:00
78.2
0015:00
76.2
0016:00
74.0
NOV. 5
1967
MLT
7.6 HRS.
U.T.
Λ
1720:00
72.8
1721:00
76.1

FIGURE 3

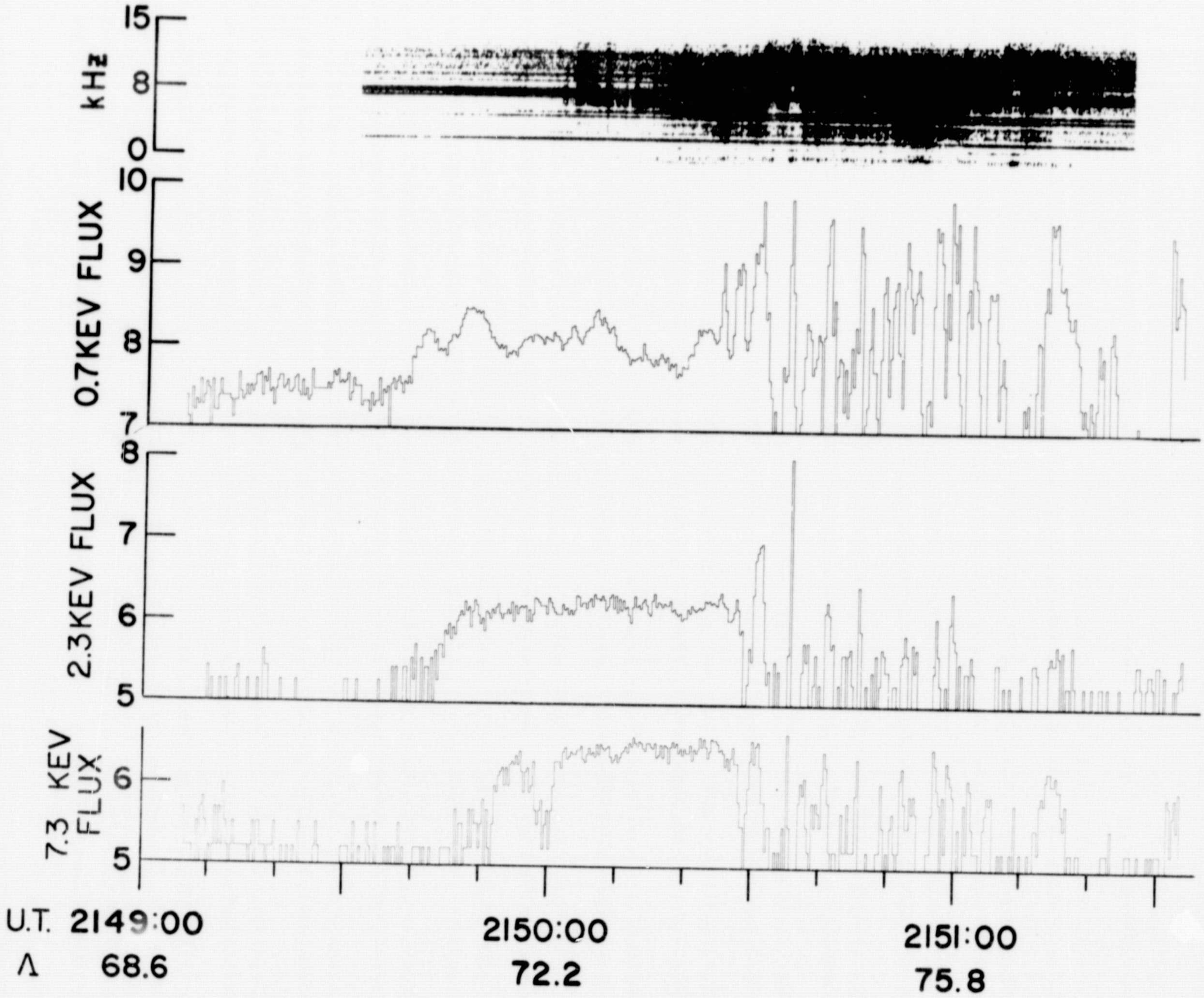
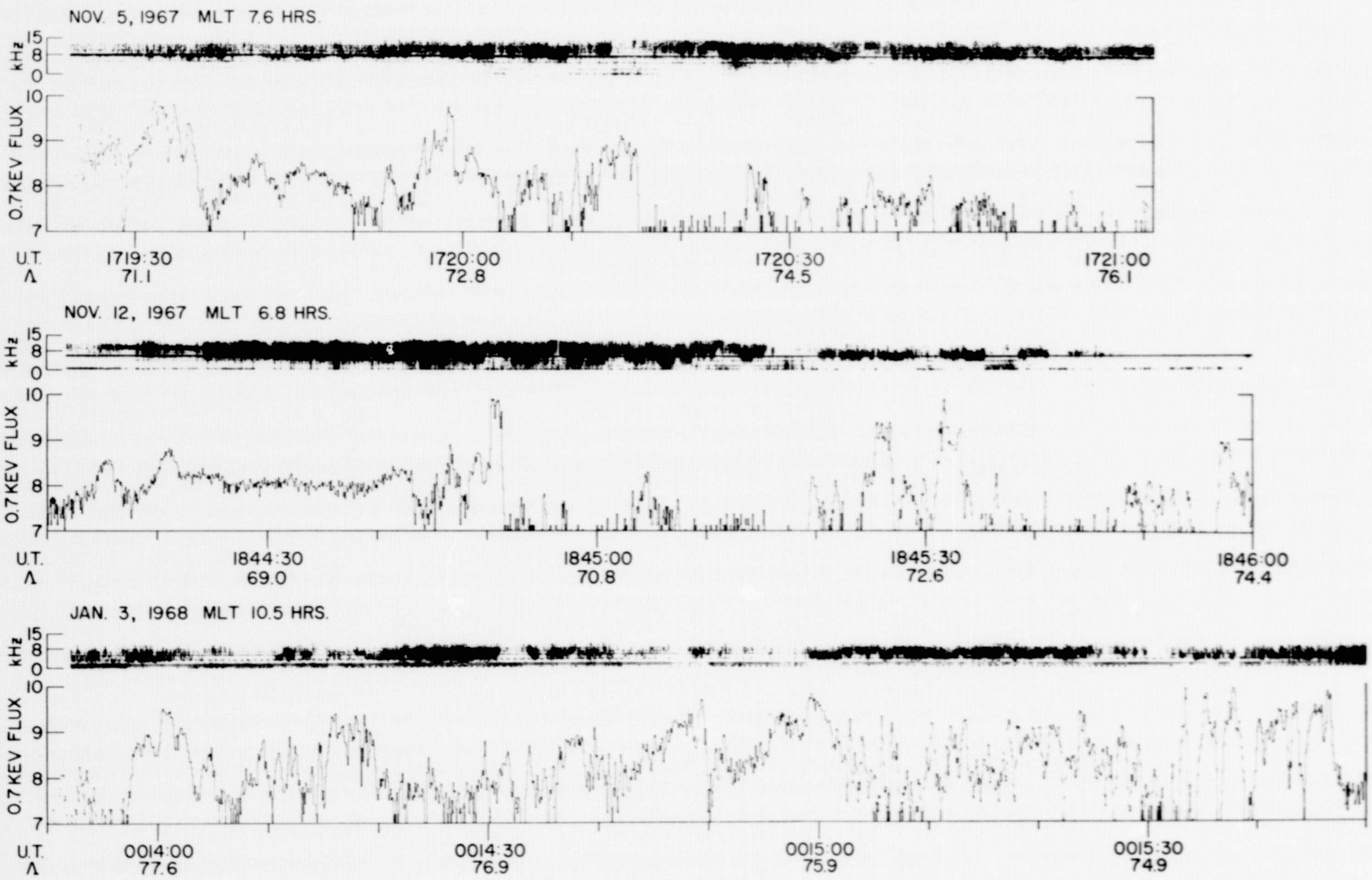
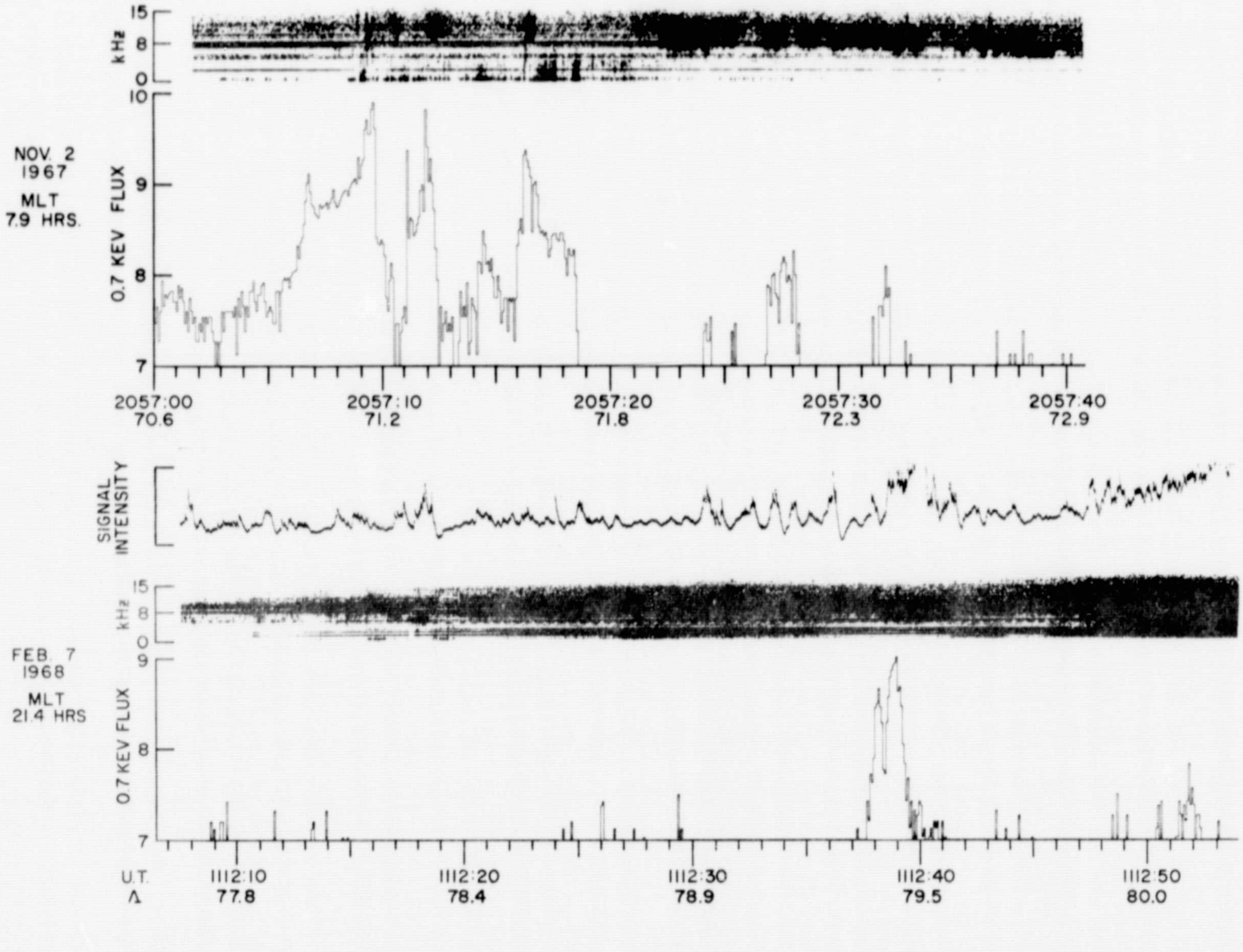

15
kHz
8
0
10
0.7KEV FLUX
9
8
7
8
2.3KEV FLUX
7
6
5
7.3 KEV FLUX
6
5
U.T. 2149:00
Λ 68.6
2150:00
72.2
2151:00
75.8

FIGURE 4



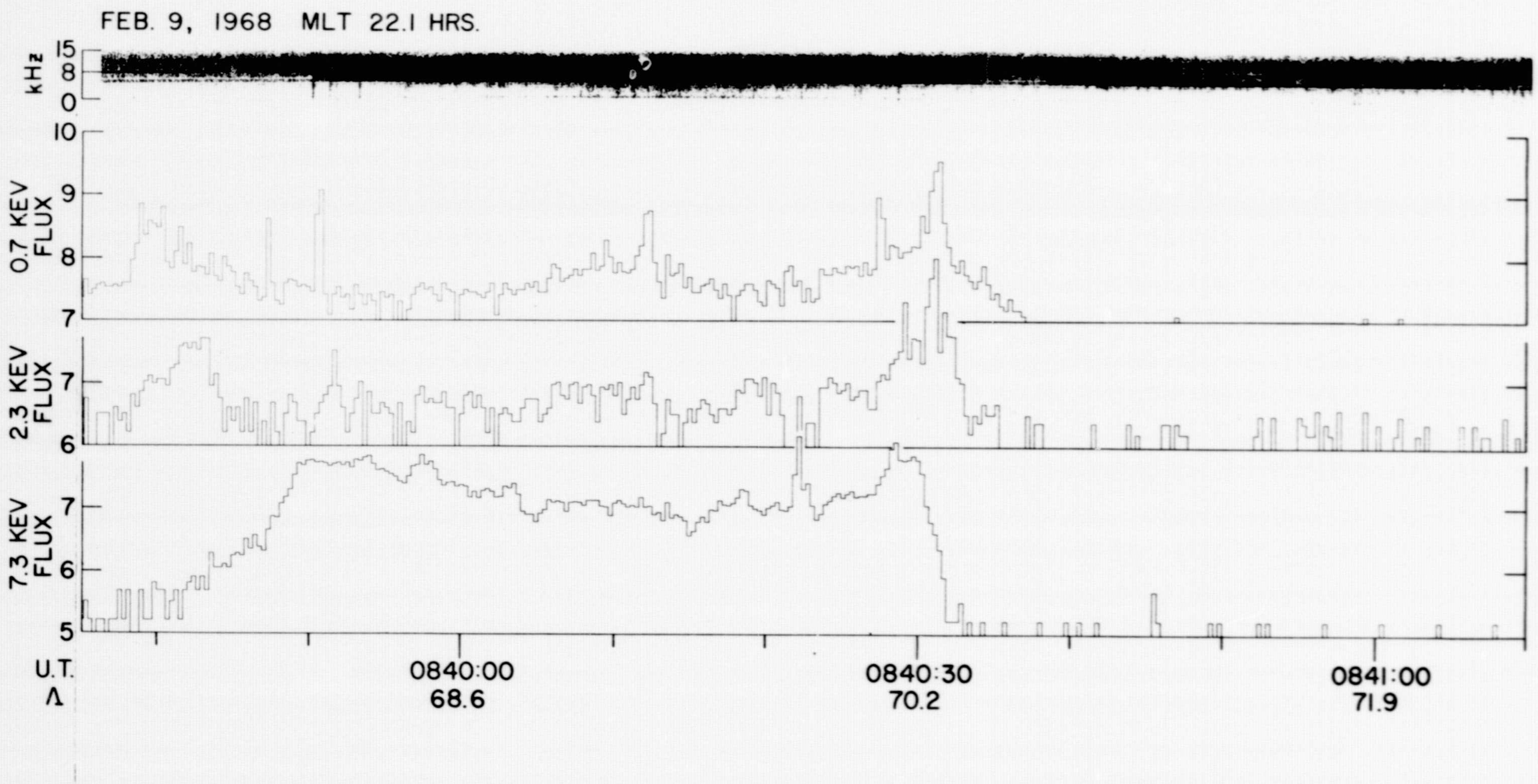
NOV. 5, 1967 MLT 7.6 HRS.
kHz
15
8
0
0.7 KEV FLUX
10
9
8
7
U.T.
Λ
1719:30
71.1
1720:00
72.8
1720:30
74.5
1721:00
76.1
NOV. 12, 1967 MLT 6.8 HRS.
1844:30
69.0
1845:00
70.8
1845:30
72.6
1846:00
74.4
JAN. 3, 1968 MLT 10.5 HRS.
0014:00
77.6
0014:30
76.9
0015:00
75.9
0015:30
74.9

FIGURE 5



15
kHz
8
0
10
NOV. 2
1967
MLT
7.9 HRS.
9
0.7 KEV FLUX
8
7
2057:00
70.6
2057:10
71.2
2057:20
71.8
2057:30
72.3
2057:40
72.9
SIGNAL INTENSITY
15
kHz
8
0
FEB. 7
1968
MLT
21.4 HRS
9
0.7 KEV FLUX
8
7
U.T.
Λ
1112:10
77.8
1112:20
78.4
1112:30
78.9
1112:40
79.5
1112:50
80.0

FIGURE 6



FEB. 9, 1968 MLT 22.1 HRS.
kHz
15
8
0
0.7 KEV FLUX
10
9
8
7
2.3 KEV FLUX
7
6
7.3 KEV FLUX
7
6
5
U.T.
Λ
0840:00
68.6
0840:30
70.2
0841:00
71.9

FIGURE 7